





Enemies or Dance partners

Technology and policy in the Energy Transition



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We all have our own perspective – this is mine

















The Energy Transition

- Maintain supply demand balance, reliably and cost effectively at all locations and times.
- Much bigger than electricity
- Nothing individually new but everything in between is new
- Enormous challenge not only technically but politically
- Need to crack the chicken and egg problem and avoid putting the cart before the horse
- MISO and Switzerland are "central" to developments











The trend is dramatic and clear – towards 100 %



Physical characteristics of variable renewable energy resources





- Inverter Based Resources (IBR) power electronics replacing synchronous machines
- Spatially disperse distributed
- Variable and somewhat difficult to predict - uncertainty





NARIS, National Renewable Energy Laboratory

Pinson, P., Madsen, H, Nielsen, H., Papaefthymiou, G. and Klöckl, B., From probabilistic forecasts to statistical scenarios of short-term wind power production, Wind Energy, volume 12, issue 1, January 2009

Different stakeholder and time frames













Governing equations

Maxwell

$$\begin{split} \oint \mathbf{E} \cdot d\mathbf{A} &= \frac{q_{enc}}{\varepsilon_0} \\ \oint \mathbf{B} \cdot d\mathbf{A} &= 0 \\ \oint \mathbf{E} \cdot d\mathbf{s} &= -\frac{d\Phi_{\rm B}}{dt} \\ \oint \mathbf{B} \cdot d\mathbf{s} &= \mu_0 \varepsilon_0 \frac{d\Phi_{\rm E}}{dt} + \mu_0 i_e \end{split}$$











Electricity is different but power systems are the same



Valuing dedicated storage in electricity grids



EASAC policy report 33

May 2017

ISBN: 978-3-8047-3729-7

This report can be found at www.easac.eu

Science Advice for the Benefit of Europe



SPOT PRICING OF ELECTRICITY

Fred C. Schweppe Michael C. Caramanis Richard D. Tabors Roger E. Bohn



Kluwer Academic Publishers Boston/Dordrecht/London

The Transition is a Journey but no new bicycle













- ACTUAL SYSTEM GENERATION - ACTUAL WIND GENERATION

Global Power System Transformation (G-PST) Consortium



https://globalpst.org/

https://globalpst.org/wp-content/uploads/042921G-PST-Research-Agenda-Master-Document-FINAL updated.pdf

GLOBAL PST CONSORTIUM

Bring it all together Institutionally for Transformation of the Global Power System





G-PST and Policy





https://www.esig.energy/wpcontent/uploads/2021/08/ESIG-Redefining-Resource-Adequacy-2021.pdf



ENSURING NOT ONLY CLEAN ENERGY, BUT RELIABILITY

ENERGY SYSTEMS

The Intersection of Resource Adequacy and Public Policy



https://globalpst.org/wpcontent/uploads/ESIG-GPST-RA-policybrief-2021.pdf

Going towards 100 % in North East of North America





No trade

-Current Trans. Cap.

----Optimal Trans. Cap.

← Current Trans. Cap. + Inst. Integration

Optimal Trans. Cap. + Inst. Integration





Engineering is the art of approximation – you should know the answer before you do the analysis









Source: JRC 2012 & Juha Kiviluoma

Some laws we know others it is too early to tell

Energy Evolution – Laws of Thermodynamics

Digital Revolution – Moores Law







Source: Ronan Doherty

Conclusions

- The energy transition requires discipline
- The laws of physics are not flexible
- Policies may need to adapt
- Good ideas may have a poor outcome
- Global dance partners are needed





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- My students and colleagues



https://globalpst.org/



https://www.esig.energy/